Chapter X: Data Center IT Efficiency Measures

The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures

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1 Measure Description

Data centers use 2% of the electricity in the United States. [1] A typical data center has 100 to 200 times the energy use intensity of a commercial building. There are tremendous opportunities to save energy in a data center, with reductions in energy use as high as 80% between an inefficient and efficient data center.[2] Data center efficiency measures generally include the following categories:

- Power infrastructure (e.g., more efficient uninterruptible power supplies, power distribution units)
- Cooling (e.g., free cooling, variable-speed drives (VSDs), temperature and humidity set points)
- Air flow management (e.g., hot aisle/cold aisle, containment, grommets)
- IT efficiency (e.g., server virtualization, efficient servers, data storage)

This chapter focuses on **IT measures in the data center** and examines the techniques and analysis methods used to verify savings from improving the efficiency of two specific pieces of IT equipment -- servers and data storage. This chapter covers options from two categories:

- Using more efficient server and data storage equipment
- Managing servers and data storage equipment to work more efficiently

The next section describes a number of the common IT measures that save energy in the data center.

1.1 Server Virtualization

In the past, data center operators would run a single application on each server. This "one workload, one box" approach means servers tend to run at a low "utilization rate" – the fraction of total computing resources engaged in useful work.[3] A 2012 New York Times article cited two sources that estimated the average server utilization rate to be 6 to 12%.[4] Another study stated that the one workload, one box approach leads to 90% of all x86 servers running at less than 10% utilization, with a typical server running at less than 5% utilization.[5]

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1 Koomey, J. "Growth in Data Center Electricity Use in 2005 to 2010." August 1, 2011. Available online at: www.analyticspress.com/datacenters.html

2 U.S. Department of Energy. "Energy 101: Energy Efficient Data Centers." May 31, 2011. Available online at: http://www.youtube.com/watch?v=xGSdf2uLtlo

3 EPA ENERGY STAR. "Consolidation of Lightly Utilized Servers." Available online at: http://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_consolidation

4 Glanz, J. "Power, Pollution and the Internet." *The New York Times*, September 22, 2012. Available online at: www.nytimes.com/2012/09/23/technology/data-centers-waste-vast-amounts-of-energy-belying-industry-image.html?pagewanted=all

5 Talaber, R. (editor); Brey, T.; Lamers, L. "Using Virtualization to Improve Data Center Efficiency." Green Grid White Paper (p. 10). Available online at: http://www.thegreengrid.org/Global/Content/white-papers/Using-Virtualization-to-Improve-Data-Center-Efficiency

With server virtualization, administrators can run multiple applications on one physical host server and consolidate server resources. In other words, multiple virtual servers can work simultaneously on one physical host server. Therefore, instead of operating many servers at low utilization, virtualization combines the processing power onto fewer servers that operate at higher total utilization.

1.2 More Efficient Servers

ENERGY STAR-certified servers have been available since 2009. The ENERGY STAR server specification covers four server form factors (blade, multi-node, rack-mounted, and pedestal) and allows a maximum of four process sockets per server (or per blade or node). ENERGY STAR servers must also have the following features:

- Efficient power supplies to limit power conversion losses;
- Improved power quality;
- Idle power draw limits for rack-mounted or pedestal servers with one and two processors;
- Results of the Server Efficiency Rating Tool (SERT) tests to accommodate comparison of server efficiency under different usage scenarios;
- Ability to measure real-time power use, processor utilization, and air inlet temperature;
- Advanced power management features and efficient components to save energy across various operating states, including idle; and
- A Power and Performance data sheet for purchasers that standardizes key information on energy performance, features, and other capabilities.

On average, ENERGY STAR servers are about 30% more energy-efficient than standard servers. The servers are particularly efficient at low loads due to processor power management requirements that reduce power consumption when the servers are idle.[6]

1.3 Data Storage Management[7]

Data storage resource management tools help data storage administrators more efficiently and effectively provision and manage data storage. This entails using tools to create “maps” and “pools” of available storage across servers and disks and utilizing these disparate “chunks” of storage as if they were one system. Some tools include:

- **Automated storage provisioning**: 1) improves storage efficiency through right-sizing; 2) identifies and reallocates unused storage, and; 3) increases server capacity by improving utilization of existing storage.[8]

6 This and more information on ENERGY STAR server specifications is available at: www.energystar.gov/products

7 Clark, T.; Yoder, A. , Yoder, Allen. “Best Practices for Energy Efficient Storage Operations Version 1.0.” Storage Networking Industry Association’s Green Storage Initiative. October 2008. Available online at: http://www.snia.org/sites/default/files/GSI_Best_Practices_V1.0_FINAL.pdf

8 Netapp. “Simple Provisioning of Your Unified Storage Environment.” Available online at: http://www.netapp.com/us/technology/unified-storage/simple-provisioning.aspx

- **Deduplication software** can condense the amount of data stored at many organizations by more than 95% by finding and eliminating unnecessary copies. Over half of the total volume of a typical company's data is in the form of redundant copies.
- **Thin provisioning** allocates storage on a just-enough, just-in-time basis by centrally controlling capacity and allocating space only as applications require the space. Thus, administrators can allocate space for an application with data storage needs they expect will increase over time, but only power storage currently in use.
- Redundant array of independent disks **(RAID) Level**) is a storage technology that combines multiple disk drive components into a single logical unit. RAID 1 creates a duplicate copy of disk data but also doubles the storage and power consumption. For storage that is not mission critical, RAID 5 guards against a single disc drive failure in your RAID set by reconstructing the failed disc information from distributed information on the remaining drives. Requiring only one extra redundant disc, RAID 5 saves energy although it does sacrifice some reliability and performance. For a 10 disc array, going to an 11-disc RAID 5 level (one extra disc) from a 20-disc RAID 1 level (duplicate copy) configuration would save 45% of data storage energy use.
- **Tiering Storage** automatically stores low-priority data—rarely accessed information—on higher latency equipment that uses less energy.

1.4 More Efficient Data Storage Equipment[9]

There are a number of data storage equipment types that use less energy including:

- **Lower Speed Drives.** Higher spin speeds on high performance hard disc drives (HDDs) (e.g., 15K rpm SAS drives) mean faster read/write speeds. All things being equal, power use is proportional to the cube of disc spin speed. To reduce energy use of storage, storage administrators should look for the slower drives (e.g., 7.5K rpm SATA drives) available to accommodate the specific tasks at hand.
- **Massive Array of Idle Discs (MAID).** MAID is more energy efficient than older systems and is often a good solution for tier 3 storage (data accessed infrequently). MAID saves power by shutting down idle disks. It powers the disks back up only when an application needs to access the data.
- **Solid State Drives (SSDs).** Energy-saving, solid-state storage is increasingly becoming an energy-efficient option. With no spinning disks to power, SSDs have "read" speeds that are an order of magnitude faster than hard discs. For example, compared to a 7.2K rpm SATA disk, an SSD consumes only one ninth the power per byte stored.[10] SSDs are more expensive than conventional hard disc options.

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9 Yoder, A."Technologies for Green Storage." Storage Networking Industry Association presentation." 2012. Available online at: snia.org/emerald

10 Pflueger, J. "Understanding Data Center Energy Intensity." A Dell Technical White Paper. 2010.

- **ENERGY STAR-certified data storage.**[11] EPA's ENERGY STAR program certifies energy-efficient online data storage that:

– Employs efficient power supplies that limit power conversion losses.

– Relies on internal variable-speed fans for cooling.

– Provides features to help better manage data, which leads to reduced storage and energy consumption.

[11] For more information on ENERGY STAR certified data storage, go to: www.energystar.gov/products

2 Application Conditions of the Protocol

Unlike other efficiency measures in the Uniform Methods Project, data center IT measures are a new target for utility programs. As shown in Table 1, most utilities offer custom incentives on data center IT measures, where the applicant must calculate and demonstrate savings from data center IT equipment. Utilities pay incentives based on actual verified savings. Table 1 shows a range of six to 16 cents per kWh saved. In general, standard custom programs work in the following manner:

- A customer submits a project application that includes energy use of pre-existing equipment, equipment required by code or standard, and the efficient measure.[12] In addition, customers must specify if they are installing the efficiency measure as an early replacement (where the existing unit still has remaining useful life) or at burnout (where the existing unit is not operational).
- The utility then inspects and approves the project prior to the removal of the existing equipment/systems and the installation of new equipment/systems.
- Upon completion of the project, the utility inspects and approves the installation of the measure(s) and finalizes the incentive amount(s).

Sometimes utilities offer prescriptive incentives for server virtualization. For example, Seattle City Lights and Energy Trust of Oregon offer prescriptive incentives based on upon the number of servers retired. A company in the Seattle City Light territory could receive $900 for retiring six servers during a virtualization effort.

In addition to the significant energy savings, server virtualization improves scalability, reduces downtime, enables faster deployments and has become commonplace— especially in large data centers.[13] Due to free-ridership concerns, Silicon Valley Power's Data Center Program (limited to larger data centers) does not allow incentives for server virtualization. (In addition, the program does not allow IT equipment incentives unless specifically approved.) PG&E and BC Hydro also stopped offering server virtualization incentives due to free-ridership concerns. This trend may continue as organizations redesign data center programs to adjust to market conditions.

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12 PG&E. "2013 Customized Retrofit Application Form." Available online at: http://www.pge.com/en/mybusiness/save/rebates/ief/index.page.

13 VEEAM. "Veeam Launches V-Index To Measure Virtualization Penetration Rate." 2011. Available online at: www.veeam.com/news/veeam-launches-v-index-to-measure-virtualization-penetration-rate.html. A 2011 survey of over 500 large enterprise data centers found that 92% use virtualization to some degree.

Table 1. Examples of Data Center IT Incentives across the Country as of October 2013

Utility	Measure	Incentive Amount	Notes
Seattle City Lights[14]	Custom IT Equipment – Plug Loads	Six cents per kWh saved	Energy savings from custom projects where software or hardware deployments save energy in IT equipment
	Server Virtualization	$150 per server removed	Maximum 200 servers removed
NYSERDA[15]	Examples listed: • Energy-Efficient Servers, Storage, and Switches • Server Virtualization • Server Refresh • Storage Consolidation and Optimization • High-Performance Computing Systems	• 12 cents per kWh saved upstate • 16 cents per kWh downstate	Capped at $5 million per facility
ComEd[16]	Examples listed: • Virtualization • Consolidation • Thin-provisioning • Solid state storage	Seven cents per kWh saved	Up to 100% of the incremental cost and 50% of the total cost of the project.
Energy Trust of Oregon[17]	Virtualization	$350 per server decommissioned	10 server minimum
Arizona Public Service[18]	Example listed: Server Virtualization	Nine cents per kWh	Virtualization listed as "typical custom project," up to 75% of incremental costs
Southern California Edison[19]	Reduced Process Load	Eight cents per kWh	Also $100/kW
Silicon Valley Power[20]	Virtualization and Consolidation of Servers, IT Equipment	Not Allowed	Large data centers (greater than 350kW IT load or greater than 100 tons cooling) denied server virtualization/consolidation incentives. In general, IT measure savings are not allowed unless specifically approved by SVP.

14 Seattle City Lights. "2013 Energy Conservation Incentives: Medium and Large Commercial." Available online at: http://www.seattle.gov/light/Conserve/Business/2013Incentives.pdf

15 NYSERDA. "Data Center Incentives Through the Industrial Process and Efficiency Program." Available online at: https://www.nyserda.ny.gov/Energy-Efficiency-and-Renewable-Programs/Commercial-and-Industrial/Sectors/Data-Centers.aspx

16 ComEd. "Stay Cool While Saving Energy in Your Data Center." Available online at: https://www.comed.com/business-savings/commercial-industrial/Pages/data-centers.aspx

17 Energy Trust of Oregon. "IT Power: Rack Up the Savings." Available online at: http://energytrust.org/commercial/incentives/equipment-upgrades-remodels/Software/it-power/; "Incentives: Data Centers." Available online at: http://energytrust.org/library/forms/be_pi0195d.pdf

18 Arizona Public Service. "Retrofit & New Construction Rebates." Available online at: http://www.aps.com/en/business/savemoney/rebates/Pages/custom-rebates.aspx

19 Southern California Edison. "Data Center Energy Efficiency Program." Available online at: http://www.willdan.com/energy/DCEEP.aspx

20 Silicon Valley Power. "2013-2014 Data Center Program Rebate Application." Available online at:http://siliconvalleypower.com/Modules/ShowDocument.aspx?documentid=5561;
Silicon Valley Power. "2013 -2014 Customer Directed Rebate Application." Available online at: http://siliconvalleypower.com/Modules/ShowDocument.aspx?documentid=5102

3 Savings Calculations

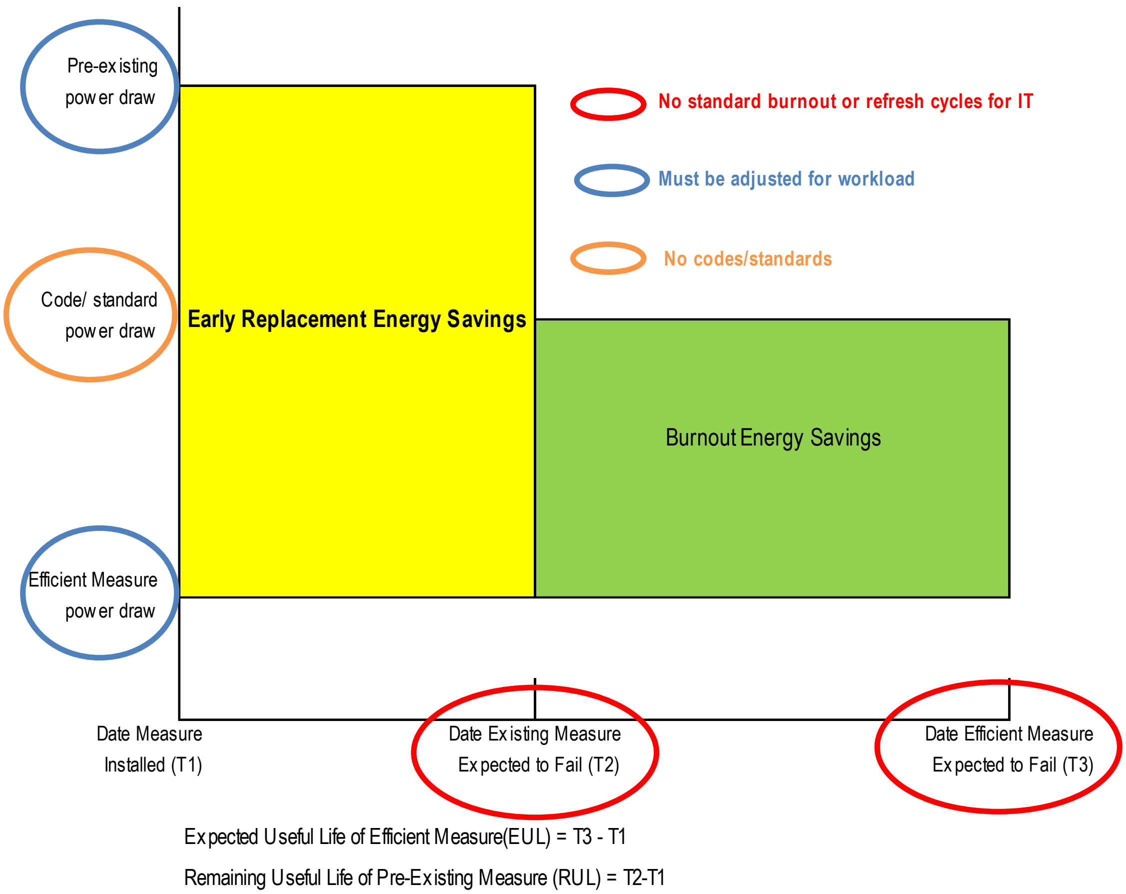
3.1 The Simple Algorithm

Calculating savings for data center IT measures presents some unique challenges. On one hand, the savings estimate can appear straightforward. For custom incentives, calculations can use data center IT equipment power and energy readings taken from uninterruptible power supplies (UPSs), power distribution units (PDUs), or rack power strips. Estimated energy savings can use power draw readings (in kW) taken before and after the measure implementation. Annual savings may be estimated using the following calculation:

$$Annual\ Energy\ Savings = 8760\ * (Power\ Draw_{\ Efficient\ IT\ Measure} - Power\ Draw_{Pre-Existing})$$

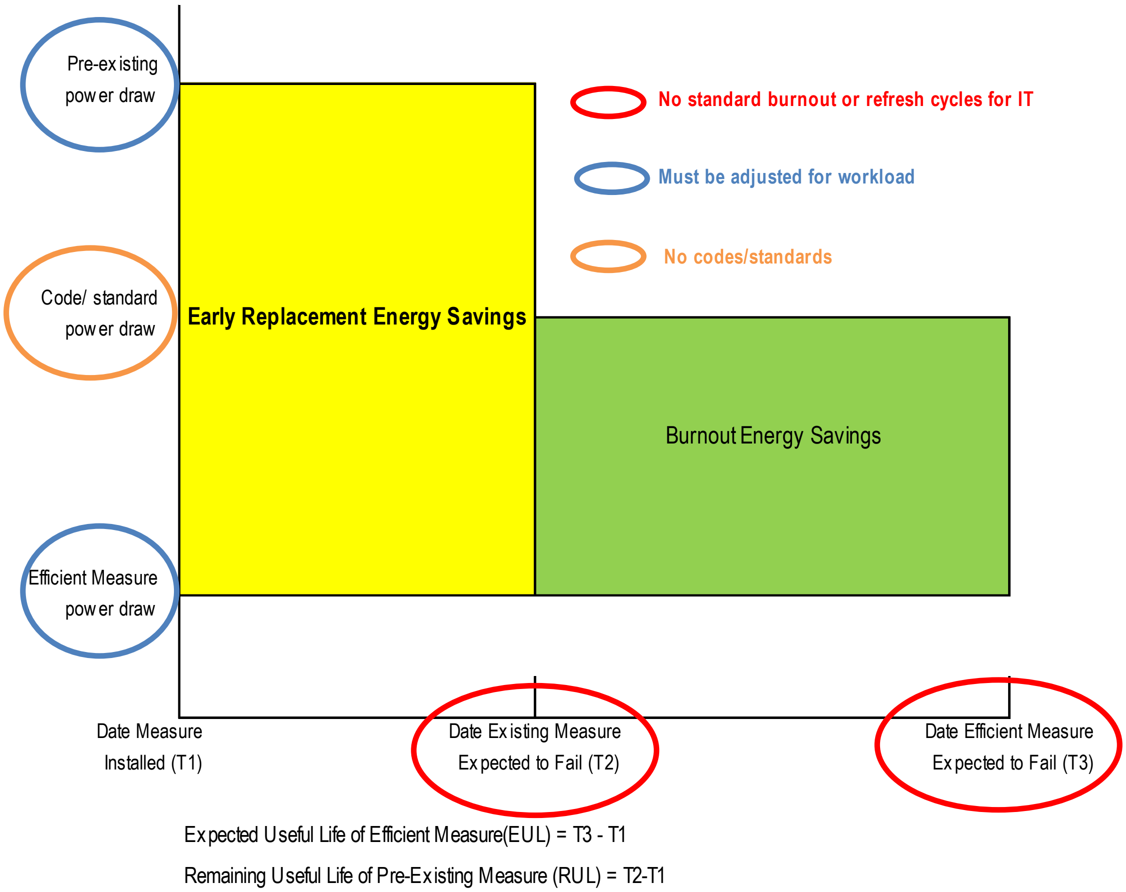
3.2 Complicating Issues with the Simple Algorithm

However, a number of issues can arise when examining the typical energy savings for a data center IT efficiency measure.



shows the typical factors involved in calculating early replacement and burnout energy savings for efficiency measures, including power draws (of efficient, standard/code, and the pre-existing measures) and the useful life (of the pre-existing measure and efficient measure).

Data center IT efficiency measures present some challenges to this calculation (shown by the blue, orange and red circles in



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- The first challenge (red circles) is that the useful life is typically hard to determine. This is because IT equipment generally does not stop working, but rather is replaced for a variety of other reasons. For example, organizations often purchase new servers when the old servers' lease ends or new server features and capabilities require it. Various IDC studies show organizations replace their servers once every three to five years.[21]

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[21] IDC. "The Cost of Retaining Aging IT Infrastructure." Sponsored by HP. Feb 2012. Available online at: http://mjf.ie/wp-content/uploads/white-papers/IDC-White-Paper_the-cost-of-retaining-aging-IT-infrastructure.pdf;

IDC. "Strategies for Server Refresh." Sponsored by Dell. 2010. Available online at: http://i.dell.com/sites/content/business/smb/sb360/en/Documents/server-refresh-strategies.pdf;

IDC. "Analyst Connection: Server Refresh Cycles: The Costs of Extending Life Cycles." Sponsored by HP/Intel. August 2012. Available online at: http://resources.itworld.com/ccd/assets/31122/detail

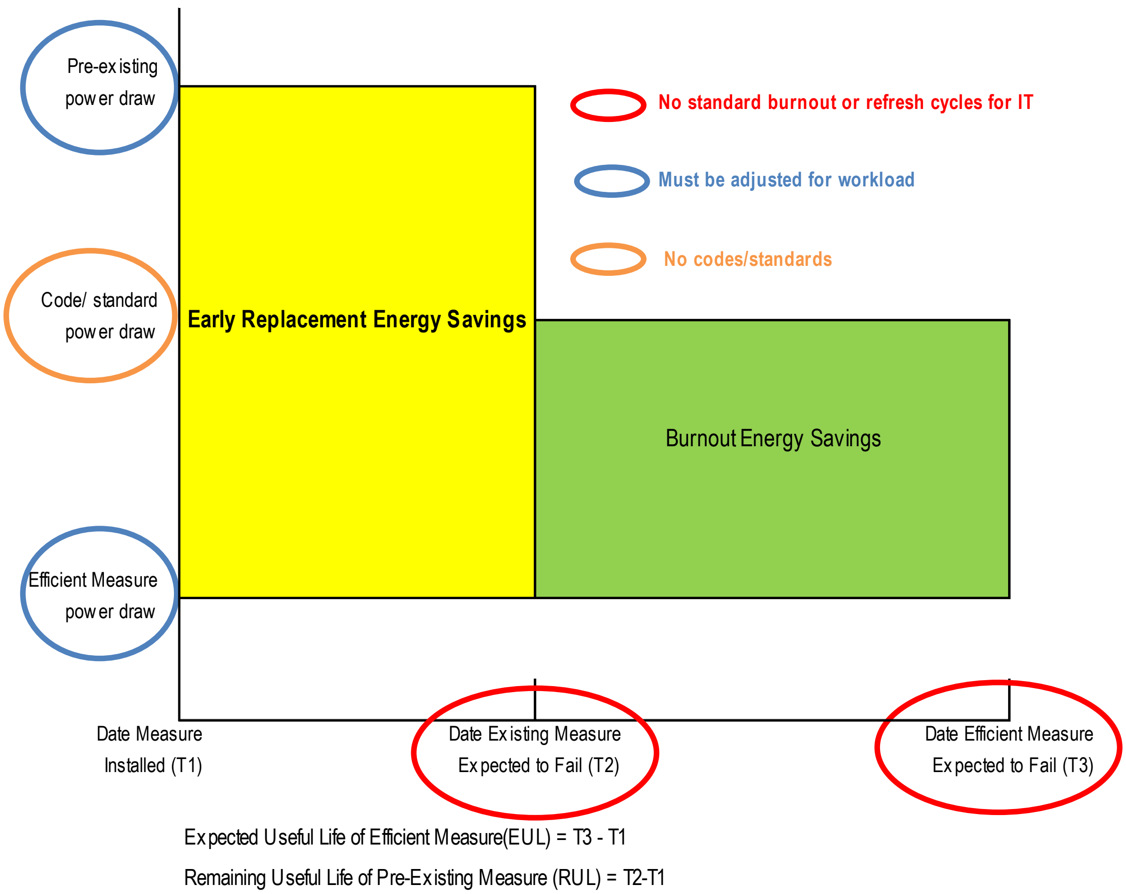

Figure 1. Challenges with determining gross savings of data center IT measures

- The second challenge (blue circles) is that power draws of IT equipment can vary with time and business demands due to changes in the useful work output required of a device (e.g., an email server workload after large-scale layoffs). Thus, it is ideal to normalize energy use for the data center workload to ensure that savings estimates are accurate. For example, if the data center workload increases right before the installation of ENERGY STAR servers, the resulting power draw of the ENERGY STAR server will be higher and savings will be underestimated. Conversely, if the data center workload decreases prior to installation of new servers, the savings will be overestimated. Many different ways to define workload per watt in a data center have been proposed and used (e.g., CPU utilization/watt, kB transmitted/watt, GB storage/watt, various benchmark workloads).[22,]

[22] The Green Grid. "Proxy Proposals for Measuring Data Center Efficiency." 2009. Available online at: http://www.thegreengrid.org/Global/Content/white-papers/Proxy-Proposals-for-Measuring-Data-Center-Efficiency

[23] However, there is not a single metric that is consistently used or considered an industry standard.

- The third challenge (orange circle) is that, unlike many other efficient measures in other sectors, there is no "typical" or "standard" efficiency for IT equipment defined by energy codes or Department of Energy standards. For these savings estimates, data center operators typically have information on the efficient measure and the pre-existing measure, but rarely have any information on the "standard" unit, making calculation of burnout savings difficult.

3.3 Calculating Data Center IT Saving

Data center IT equipment, although still in perfect working condition, is upgraded when it is no longer useful (RUL = 0) for a variety of reasons other than breaking down (e.g., expired service level agreements, antiquated feature sets, unsatisfactory workload performance issues, compatibility with hardware-based management systems).[24] In other words, "early replacement" savings do not typically apply to data center IT equipment.

Therefore, the following sections only present the savings calculations focused on estimating the burnout savings—the energy use difference between the hypothetical "standard" or "typical" equipment available on the market (not the pre-existing equipment) and the efficient equipment to be installed. **Error! Reference source not found.** shows the remaining challenges to calculating burnout savings for IT equipment.

23 Pflueger, J. "Understanding Data Center Energy Intensity." A Dell Technical White Paper. 2010.

24 Search Data Center. "The server lifecycle: Is it time for that aging server to go?" December 7, 2012. Available online at: http://searchdatacenter.techtarget.com/tip/The-server-lifecycle-Is-it-time-for-that-aging-server-to-go

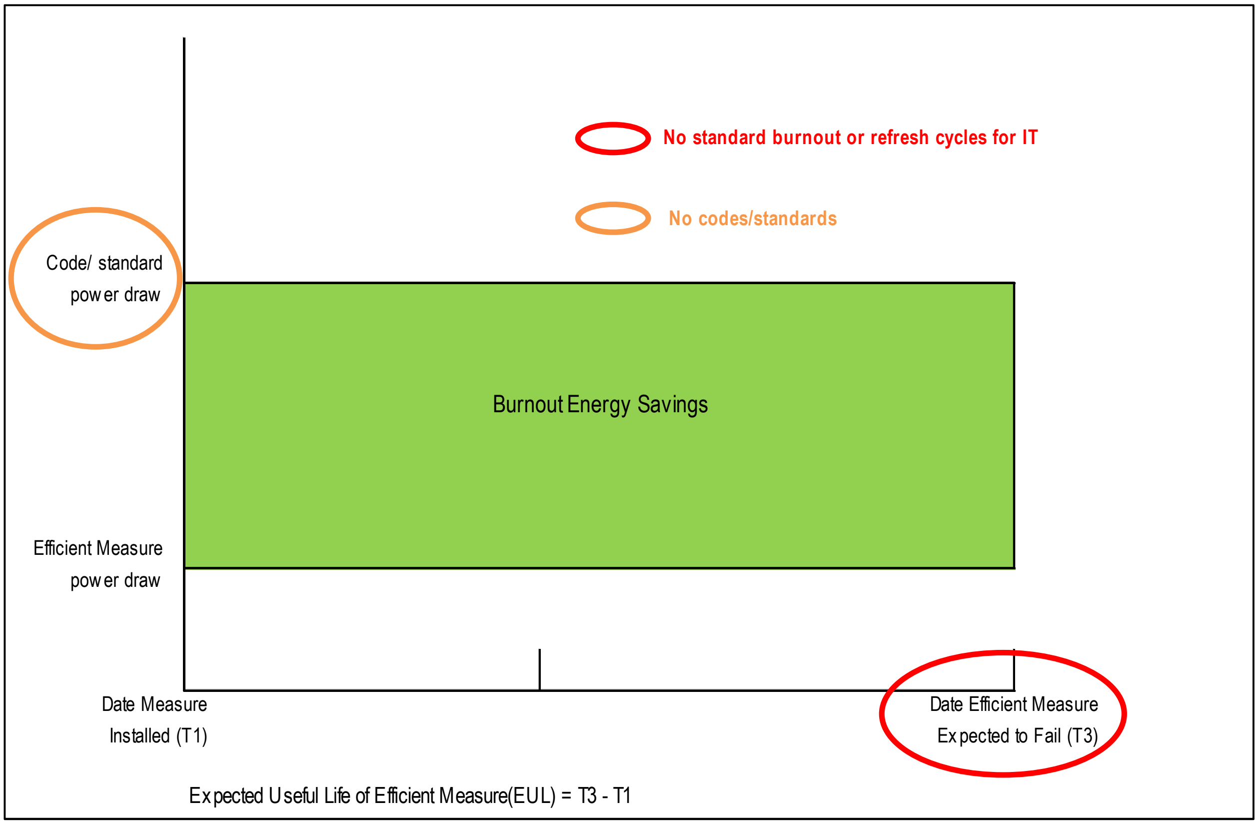

Figure 2. Challenges with determining "burnout only" gross savings of data center IT measures

3.3.1 Calculating Savings When Upgrading to More Efficient Servers

As stated earlier, manufacturers are just beginning to offer efficiency metrics (EMs) for servers to allow for comparison of server efficiency.[25] In the not-to-distant future, EMs for servers will allow for simple comparison between the efficient server and a "baseline" server, which will be established by examining the EMs of servers of similar configuration (chip sets, memory, hard drives, etc.), computational output, and year of manufacturer.

If the EM for servers decreases when the unit becomes more efficient (e.g., watts/operation), the general equation used is:

$$Annual\ Energy\ Savings_{Efficient\ Servers} = kW_{EE} * (EM_{baseline}/EM_{EE} - 1) * 8760$$

If the EM for servers increases when the unit becomes more efficient (e.g., operations/watt), the general equation used is:

$$Annual\ Energy\ Savings_{Efficient\ Servers} = kW_{EE} * (EM_{EE}/EM_{baseline} - 1) * 8760$$

Where,

[25] EPA requires reporting of the SPEC Server Efficiency Rating Tool (SERT) results for ENERGY STAR-certified servers.

kW_{EE} = power draw of new efficient server equipment

EM_{EE} = efficiency metric for efficient server

$EM_{baseline}$ = efficiency metric for baseline server

8760 = number of hours in a year as servers run 24/7 in a data center

However, at this point in time, given the limited data on EMs for servers, the simplest way to calculate savings is to only consider ENERGY STAR-certified servers as "efficient servers." Using EPA estimates of percentage savings compared to standard or typical servers, savings can be calculated as illustrated here:

$$Annual\ Energy\ Savings_{ES\ Servers} = (kW_{baseline} - kW_{ENERGY\ STAR}) * 8760$$

$$kW_{ENERGY\ STAR} = \sum_{ES=1}^{n} (kW_{ES,idle} + U_{ES} * (kW_{ES,full\ load} - kW_{ES,idle})$$

$$kW_{baseline} = kW_{ENERGY\ STAR}/(1-a)$$

This approach leads to the following simplified expression:

$$Annual\ Energy\ Savings_{ES\ Servers} = (\frac{1}{(1-a)} - 1)\ kW_{ENERGY\ STAR} * 8760$$

Where,

$kW_{ENERGY\ STAR}$ = power draw in kilowatts of ENERGY STAR server (this value can be obtained using the above calculation or via metering)

ES = ENERGY STAR servers, numbered 1 to n

$kW_{ES,\ idle}$ = power draw in kilowatts of ENERGY STAR server at idle

$kW_{ES,\ full\ load}$ = power draw in kilowatts of ENERGY STAR server at full load

U_{ES} = utilization of ENERGY STAR server

$kW_{baseline}$ = power draw of baseline servers

a = percentage ENERGY STAR server is more efficient than baseline "standard" or "typical" unit; the default of a is 0.3 since ENERGY STAR servers are 30 % more efficient on average

8760 = number of hours in a year (servers run 24/7 in a data center)

3.3.2 Calculating Savings for Server Virtualization

Server virtualization savings is a comparison of the baseline energy use of a large set of single application servers that would have been purchased normally during a server upgrade with no virtualization to a smaller set of virtual host servers, as shown in the following equation:

$$kW_{baseline} = \sum_{1}^{n}(kW_{sa,idle} + U_{sa} * (kW_{sa,full\ load} - kW_{sa,idle})$$

$$kW_{w\ Virt} = \sum_{1}^{m}(kW_{vh,idle} + U_{vh} * (kW_{vh,full\ load} - kW_{vh,idle})$$

$$Annual\ Energy\ Savings_{Virt} = (kW_{baseline} - kW_{w\ Virt}) * 8760$$

Where,

$kW_{baseline}$	= total power draw in kilowatts of all single application servers without virtualization during server refresh
sa	= single application servers, numbered 1 to n
$kW_{sa,idle}$	= power draw in kilowatts of a single application server at idle
$kW_{sa,\ full\ load}$	= power draw in kilowatts of a single application server at full load
U_{sa}	= utilization of single application server
$kW_{w\ virt}$	= total power draw in kilowatts of all virtual hosts (this value can be obtained using the above calculation or through metering the power of the installed virtual host)
vh	= virtual host servers, numbered 1 to m
$kW_{vh,\ idle}$	= power draw in kilowatts of a virtual host server at idle
$kW_{vh,\ full\ load}$	= power draw in kilowatts of a virtual host server at full load
U_{vh}	= virtual host server utilization

3.3.3 Calculating Savings for Using More Efficient Storage

As shown in the **Error! Reference source not found.**, the energy use of data storage varies by technology and disk speed. Energy use can decrease by an order of magnitude with equipment upgrades and an organization replaces faster spinning (15K rpm) fibre channel (FC) hard discs to energy efficient solid state drives (SSD).

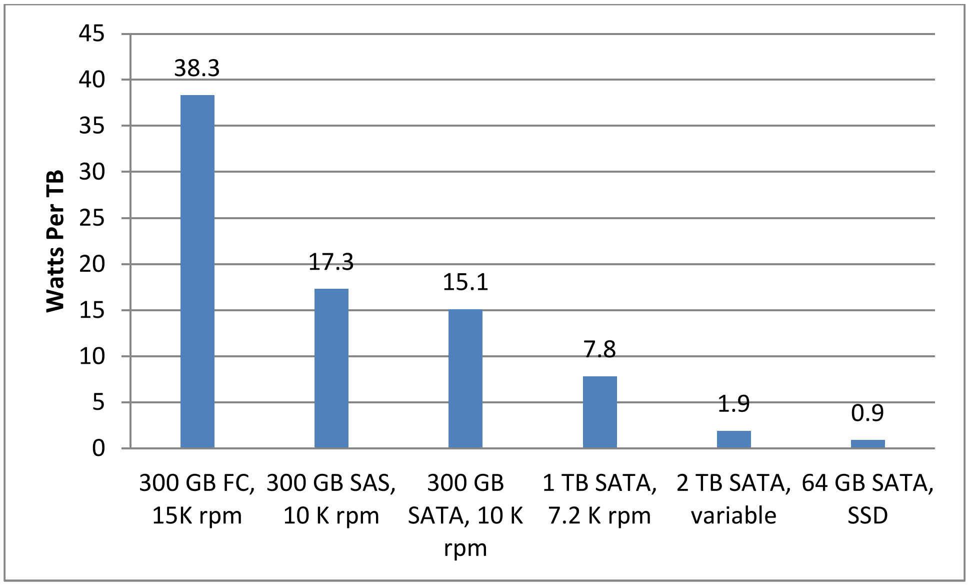

Figure 3. Watts per terabyte for various data storage types[26]

The equations used to calculate savings from upgrading to more efficient storage equipment or better managed storage include the following:

$$kW_{EE} = 1000 * StorEE \sum_{i=1}^{n} f_{EE(i)} \frac{W_{EE(i)}}{B_{EE(i)}}$$

$$kW_{baseline} = 1000 * StorBase \sum_{j=1}^{m} f_{base(j)} \frac{W_{base(j)}}{B_{base(j)}}$$

$$Annual\ Energy\ Savings_{Storage} = (kW_{baseline} - kW_{EE}) * 8760$$

Where,

kW_{EE}	= power draw in kilowatts of all energy-efficient storage devices 1 to n
$StorEE$	= total bytes stored on energy-efficient storage devices 1 to n (TB) (obtained from data storage management software)
$f_{EE(i)}$	= fraction of total bytes that is stored on energy-efficient device/array i

[26] Pflueger, J. "Understanding Data Center Energy Intensity." A Dell Technical White Paper. 2010.

$W_{EE(i)}$ = power draw in watts of an energy-efficient device/array i (this value should be metered for arrays with idle, but can come from product specifications for devices and/or arrays without idle)

$B_{EE(i)}$ = total bytes stored on an energy-efficient device/array i (TB) (obtained from data storage management software)

i = energy-efficient devices/arrays, numbered 1 to n

$kW_{baseline}$ = power draw in kilowatts of all baseline storage devices 1 to m

$StorBase$ = total bytes stored on baseline storage devices 1 to m (TB) (obtained from data storage management software)

$F_{base(j)}$ = fraction of total bytes stored that is stored on a baseline device/array j

$W_{base(j)}$ = power draw in watts of a baseline device/array j (this value should be metered for arrays with idle, but can come from product specifications for devices and/or arrays without idle)

$B_{base(j)}$ = total bytes stored on a baseline device/array j (TB) (obtained from data storage management software)

j = baseline devices/arrays, numbered 1 to m

Although information on watt/TB of storage products is becoming more prevalent for storage devices, there is a fundamental difficulty with attempting the calculation above—determining a baseline for a typical or standard storage device is not possible given the wide variety of storage devices available and the constantly changing market. Instead, similar to efficiency servers, savings calculations should limit the energy-efficient storage unit to ENERGY STAR-certified units (effective December 2013), as shown here:

$$Annual\ Energy\ Savings_{ES\ Storage} = (kW_{baseline} - kW_{ENERGY\ STAR}) * 8760$$

$$kW_{ENERGY\ STAR} = 1000 * StorES \sum_{k=1}^{n} f_{ES(k)} \frac{W_{ES(k)}}{B_{ES(k)}}$$

$$kW_{baseline} = kW_{ENERGY\ STAR}/(1-a)$$

This approach leads to the following simplified expression:

$$Annual\ Energy\ Savings_{ES\ Storage} = \left(\frac{1}{(1-a)} - 1\right) kW_{ENERGY\ STAR} * 8760$$

Where,

$kW_{ENERGY\ STAR}$	= power draw in kilowatts of ENERGY STAR storage
$kW_{baseline}$	= power draw of baseline typical or standard storage
$StorES$	= total bytes stored on ENERGY STAR storage devices 1 to n (TB) (obtained from data storage management software)
$f_{ES(k)}$	= fraction of total bytes that is stored on ENERGY STAR device/array k
$W_{ES(k)}$	= power draw of ENERGY STAR device/array k (this value should be metered for arrays with idle, but can come from product specifications for devices and/or arrays without idle)
$B_{ES(k)}$	= total bytes stored on ENERGY STAR device/array k (TB) (obtained from data storage management software)
k	= ENERGY STAR devices/arrays, numbered 1 to n
a	= percentage ENERGY STAR storage is more efficient than typical or standard storage; (ENERGY STAR has not issued this data yet but will after it collects more data on certified units)
8760	= number of hours in a year (servers run 24/7 in a data center)

3.3.4 Lifetime and Peak Demand Savings for Server and Storage Efficiency

The equation used to calculate IT lifetime savings for server virtualization, efficient server upgrades, or efficient storage is::

$$Lifetime\ Energy\ Savings_{IT} = Annual\ Energy\ Savings_{IT} * EUL$$

Where,

EUL	= expected useful life based on IT upgrade cycle of data center (as a default use 5 years for smaller data centers and 3 years for larger data centers.)

The equation used to calculate peak demand savings, based on 24/7 operation of servers and storage is:

$$Peak\ Demand\ Savings_{IT} = Annual\ Energy\ Savings_{IT}/8760$$

3.4 Calculating Additional Cooling and Power Infrastructure Savings

The total energy savings, which includes additional cooling and power infrastructure savings, can be calculated by multiplying the energy savings from an IT upgrade by the data center's power usage effectiveness (PUE). PUE is the total data center energy use (lights, HVAC, UPS losses, IT) divided by the IT energy use. As a data center becomes more efficient, PUE moves towards 1. According to a 2013 recent Uptime Institute industry survey, PUE is roughly 1.65 on average.

To calculate total energy and demand savings, the following equations should be used:

$$Annual\ Energy\ Savings_{Total} = PUE * Annual\ Energy\ Savings_{IT}$$

$$Peak\ Demand\ Savings_{\ Total} = PUE * Peak\ Demand\ Savings_{\ IT}$$

4 Measurement and Verification Plan

For IT measures in a data center, the following two major components of the savings must be examined:

- The power draw of the efficient data center IT equipment.
- The efficiency standards for the measure and the efficiency standard for the available IT equipment. (This information allows for development of savings estimates.)

On the surface, the requirements of a typical measurement and verification (M&V) plan for data center IT appear to be very similar to other energy efficiency measures (e.g., HVAC, lighting). However, given the limited amount of data for efficiency metrics in the IT space and the variability of access to data center power draw data, the M&V plan must be flexible and accommodate a wide variety of available data.

4.1 International Performance Measurement and Verification Protocol (IPMVP) Option

IPMVP Option A (i.e., Retrofit Isolation: Key Parameter Measurement) is the best approach for data center IT measures because of its flexibility. Option A relies on both field measurement of the key performance parameter(s) and estimates of key parameters not selected for field measurement. Data center IT measure energy use estimates will rely on estimates based on historical data, manufacturer's specifications, or engineering judgment. Other IPMVP options do not provide this flexibility:

- Option B, which requires measurement of all energy quantities to compute savings, is not a viable approach because:
  - Data center IT equipment "burnout" savings calculations require that the current codes or standards be used as baseline equipment. This baseline equipment is not installed and hence, cannot be metered, and cannot fit into an Option B methodology, which requires metering.
  - In general, a risk adverse manager will not allow metering of IT equipment in a data center. However, the manager may be able to share data gathered from metering equipment installed at the uninterruptible power supply, power distribution units, or in-rack smart power strips.
- Option C, which uses pre/post billing analysis, is also not a viable approach. As with Option B, the baseline used in the "burnout" savings calculation is based on current codes or standards and not represented in the pre-implementation electricity bills.

4.2 Verification Process

The verification process involves examining the core assumptions in the development of the savings estimate. The process should include the following steps:

- Desk reviews of information pertaining to:
  - Energy-efficient IT equipment

- Baseline standard or typical IT equipment
- Efficiency metrics
- Efficiency of ENERGY STAR server and storage
- Power Draws
- EUL
- PUE

- On-site audits to confirm:

- Installation of efficient IT equipment
- Power draws of efficient IT equipment based on spot readings of UPS, PDU, power strip, and server power
- Utilization of servers

4.3 Data Requirements/Collection Methods

This section provides details on the type of data needed, along with how to collect the data, to verify the key inputs into an energy saving calculation for data center IT equipment.

- *Number of energy-efficient IT equipment units installed.* Reviewers should examine work order and invoices and conduct site visits to confirm the purchase of efficient units and their installation.
- *Baseline IT equipment unit.* Since savings estimates are limited to only burnout savings estimates, the reviewer must carefully examine how the applicant determined the baseline standard or typical IT equipment, which is not specified in federal building codes and standards. Baseline standard or typical IT equipment should:

- Provide the same performance as the energy-efficient IT unit (e.g., same storage capacity in data storage units, same chip set, memory, storage in servers)
- Be manufactured in the same year as the energy-efficient IT unit.

- *Efficiency metrics of IT equipment.* The Green Grid is developing a number of efficiency metrics for IT equipment. More and more manufacturers are including these efficiency metrics in their specification sheets. In fact, manufacturers of ENERGY STAR-certified servers and data storage are required to include efficiency metric information. Examples of these metrics include:

- SPEC Server Efficiency Rating Tool (www.spec.org.sert)
- Storage Networking Industry Association (SNIA) Emerald Power Efficiency Measurement specification. (www.sniaemerald.com)

- *Percent savings for ENERGY STAR servers and storage, a.* Reviewers should confirm these estimates at the ENERGY STAR websites for servers and data storage: www.energystar.gov/products.

- *Power draws of IT equipment.* For power draws, reviewers should compare alternative methods for estimating power draw such as these:

– Rough estimations of server power draw can use idle power draw, full load power draw, and server utilization. ENERGY STAR servers are required to report full load and idle power draws. Utilization of servers can be derived from the data center's server performance software or estimated from available industry data. For example, single application server utilization on averages 9% .[27] On average, virtual host server utilization is 50%. [28]

– Rough estimations of data storage power draw can use the rated watts per terabyte stored on the storage unit.

– Although these rough estimations for IT equipment power draw are reasonable, a more accurate method is to download directly from data center energy management systems, uninterruptible power supplies, power distribution units, power strip with metering capability, or even at the server or data storage unit. ENERGY STAR-certified servers are required to "provide data on input power consumption (W), inlet air temperature (degrees C), and average utilization of all logical CPUs."[29] Power draw data should be averaged over a month to account for differences in server load on weekends and nights or the differing levels of storage used due to data storage resource management tools. If IT equipment power draw is measured at the PDU or UPS, it should be adjusted to reflect the lower draws of the actual IT equipment (due PDU and UPS power losses) by multiplying by PDU or UPS efficiency (which is generally above 90%).

- *EUL.* In general, as stated earlier, IT upgrades occur every three to five years but can certainly vary by organization. To verify EUL, the following type of justification should be used:

– Length of service level agreements

– Time period since last IT upgrade

- *PUE* varies a great deal across data centers. National average PUE should not be used. Most larger data centers will have an in-house estimate of PUE that is tracked over time. The Green Grid provides guidance on how to measure.[30]

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27 Glanz, J. "Power, Pollution and the Internet." *The New York Times*. September 22, 2012. New York Times article cited two sources that estimated the average server utilization rate to be 6 to 12%. Available online at: www.nytimes.com/2012/09/23/technology/data-centers-waste-vast-amounts-of-energy-belying-industry-image.html?pagewanted=all

28 Talaber, R. (editor); Brey, T.; Lamers, L. "Using Virtualization to Improve Data Center Efficiency." Green Grid White Paper (p. 10). Available online at: http://www.thegreengrid.org/Global/Content/white-papers/Using-Virtualization-to-Improve-Data-Center-Efficiency. Mentions a target of 50% server utilization when setting up your virtual host.

29 EPA. "ENERGY STAR Program Requirements for Computer Servers." October 2013. Section 5.1. Available online at: www.energystar.gov/products

30 The Green Grid. "PUE: A Comprehensive Examination of the Metric." 2012. Available online at: http://www.thegreengrid.org/en/Global/Content/white-papers/WP49-PUEAComprehensiveExaminationoftheMetric

5 Other Evaluation Issues

The following two issues can complicate the evaluation of data center IT equipment savings:[31]

- **Long Lead Times:** Data center deployments often take a longer to complete than other types of energy-efficiency engagements. All projects, whether related to IT equipment or its supporting infrastructure, require careful planning and execution. These long lead times may contribute to difficulties in evaluating savings because the project is simply not completed by the time the evaluation takes place. Evaluating savings before an IT upgrade is complete may result in significantly smaller savings than originally estimated. Given these long lead times, reviewers should carefully examine building plans and forecast project savings to start small and increase annually.
- **Short Production Cycles:** Servers and many other types of IT equipment have annual production cycles due to frequent technological upgrades. These product cycles are unlike other product categories such as HVAC equipment, food service equipment, and residential appliances, which generally advance over multiyear timeframes. Technological advances can cause data center equipment to become antiquated with relative frequency. Thus, savings calculations for IT equipment are based on a "burnout" scenario —where the efficient measure is compared to the baseline standard or typical equipment available at the time of installation. During the evaluation, reviewers must take great care to examine the baseline equipment that was available at the time the efficient IT measure was installed. If the baseline equipment is not from the correct time period, given the short production cycles and how quickly IT equipment productivity increases over time, savings could be significantly underestimated.

[31] EPA ENERGY STAR. "Understanding and Designing Energy-Efficiency Programs for Data Centers." November 2012. Available online at: http://www.energystar.gov/ia/products/power_mgt/ES_Data_Center_Utility_Guide.pdf?ff29-42fa